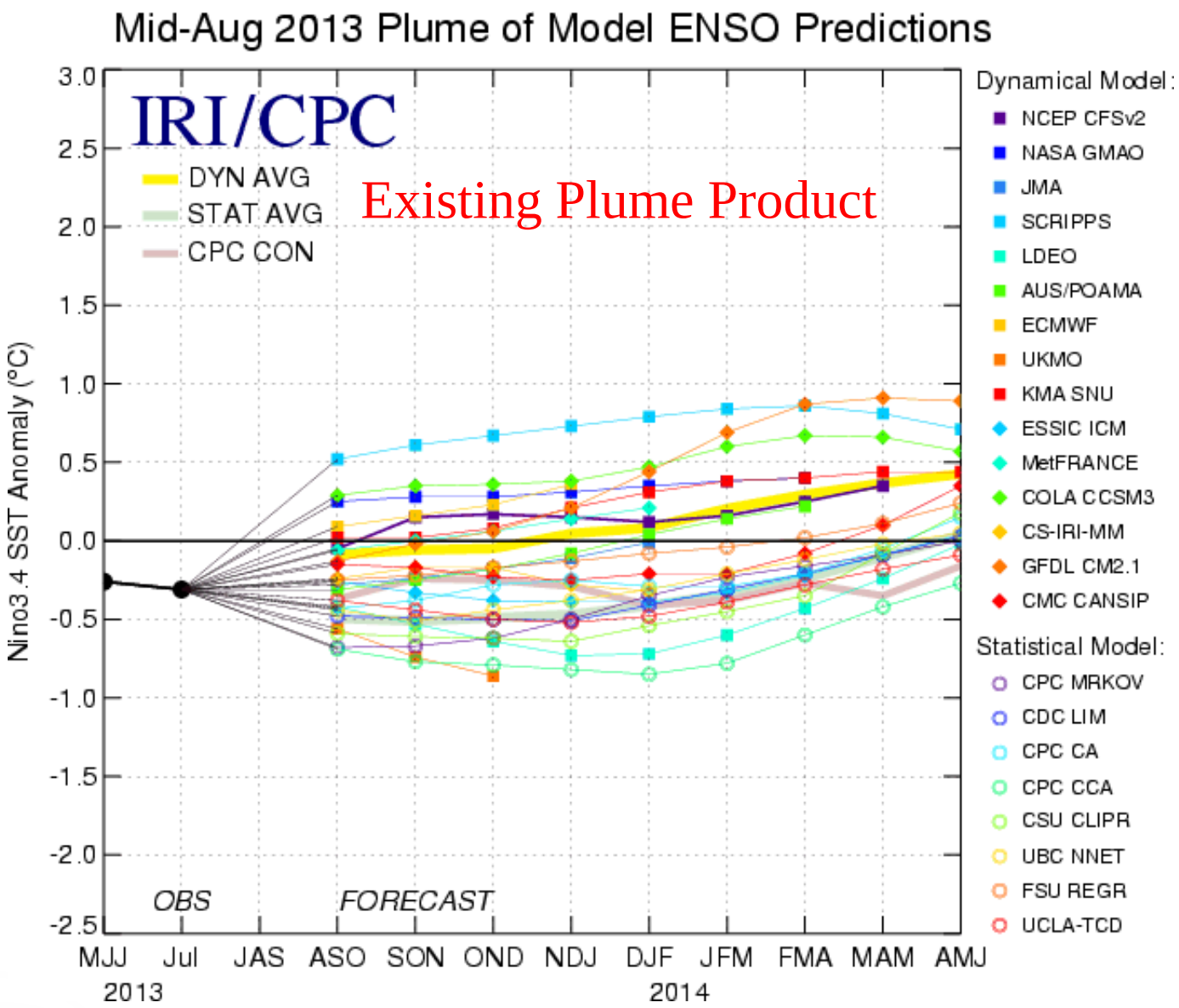
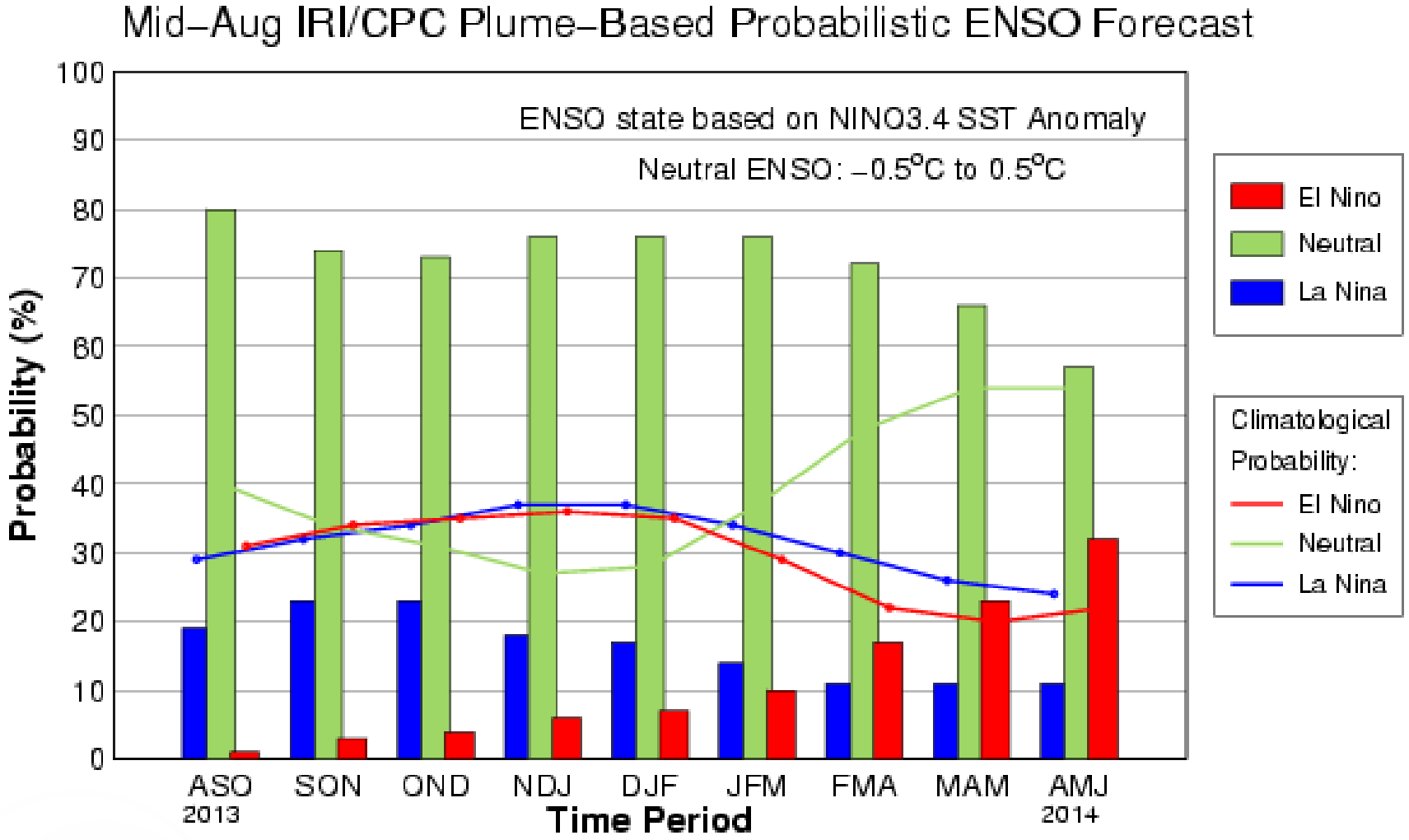
Developing a More Reliable and Usable ENSO Prediction Plume

Tony Barnston, Mike Tippett,
Huug van den Dool, David Unger

International Research Institute
for Climate and Society
Earth Institute | Columbia University


Mid-Aug 2013 Plume of Model ENSO Predictions
IRI/CPC
DYN AVG
STAT AVG
CPC CON
Existing Plume Product
Nino3.4 SST Anomaly (°C)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
OBS
FORECAST
MJJ
Jul
JAS
ASO
SON
OND
NDJ
DJF
JFM
FMA
MAM
AMJ
2013
2014
Dynamical Model:
NCEP CFSv2
NASA GMAO
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
MetFRANCE
COLA CCSM3
CS-IRI-MM
GFDL CM2.1
CMC CANSIP
Statistical Model:
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD

Probability Forecast Based on Grand Mean from Existing Plume Product



Problems with current plume product

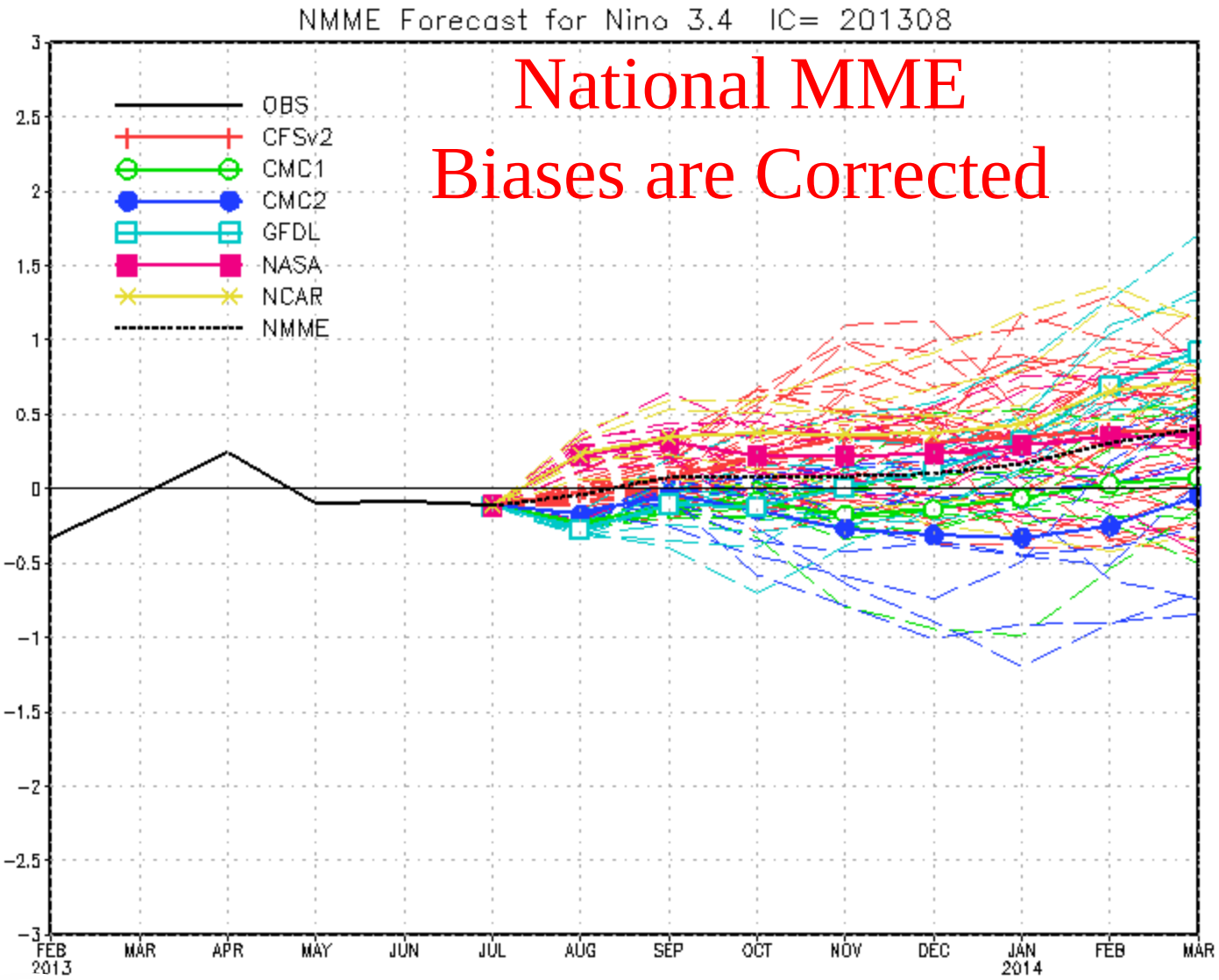
1. Mixing of slightly different base periods used for anomalies

2. Spread within individual models is ignored:

- Individual ensemble members in dynamical models
- Standard error of estimate in statistical models

3. Model biases not corrected.

4. No attempt made to objectively estimate and provide probability distribution; user sees the spread among the model forecasts and surmises uncertainty on own.


NMME Forecast for Nino 3.4 IC= 201308
National MME
Biases are Corrected
OBS
CFSv2
CMC1
CMC2
GFDL
NASA
NCAR
NMME
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
FEB 2013
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN 2014
FEB
MAR

Six NMME Models Used Here

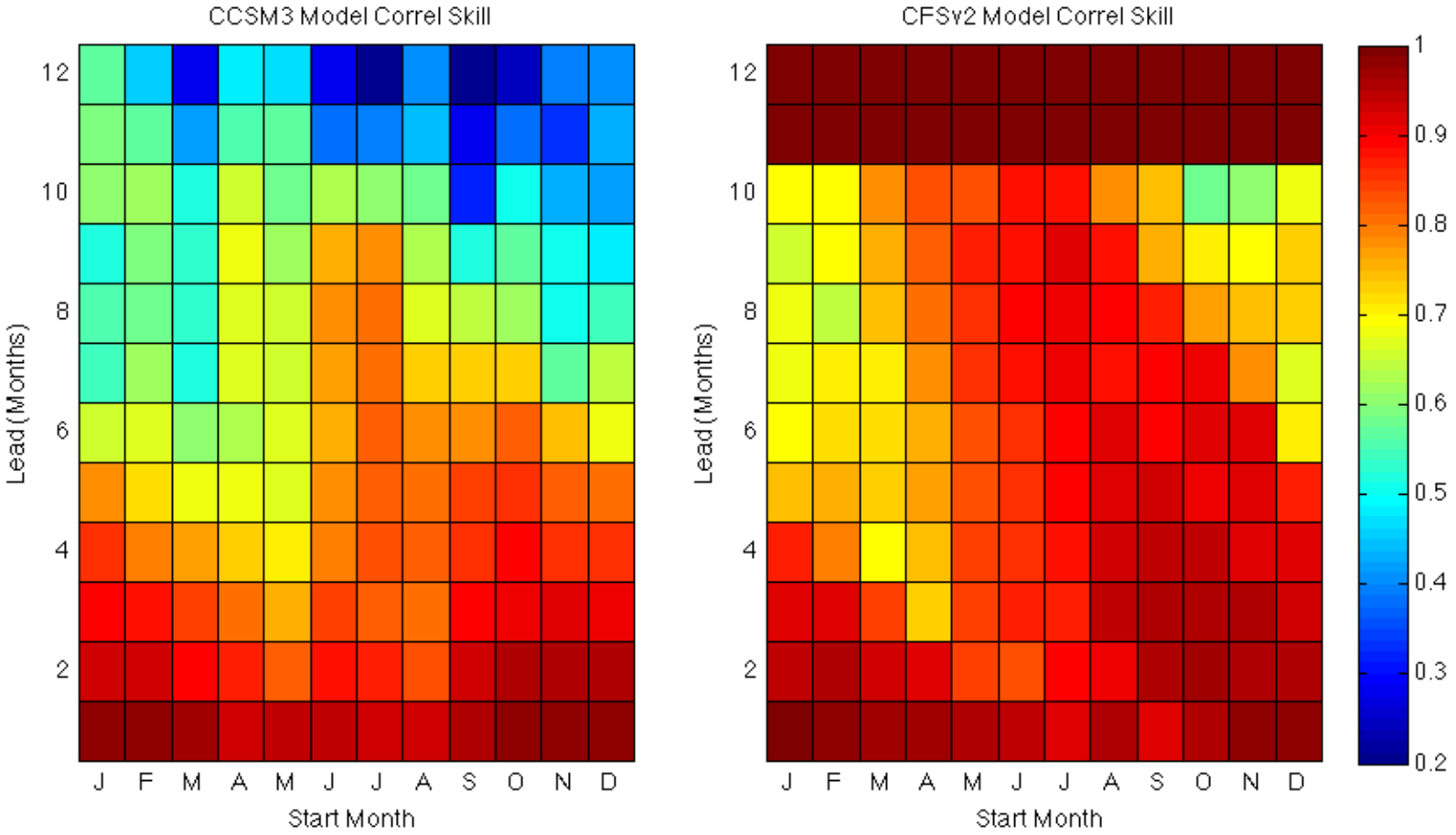
Model	#Ens Members	Max Lead
NCAR/Univ. Miami CCSM3	6	12
NOAA/NCEP CFSv2	24	10
Canada CMC1	10	12
Canada CMC2	10	12
NOAA GFDL	10	12
NASA	11	9

Hindcast period: 1982-2010 (29 yrs)

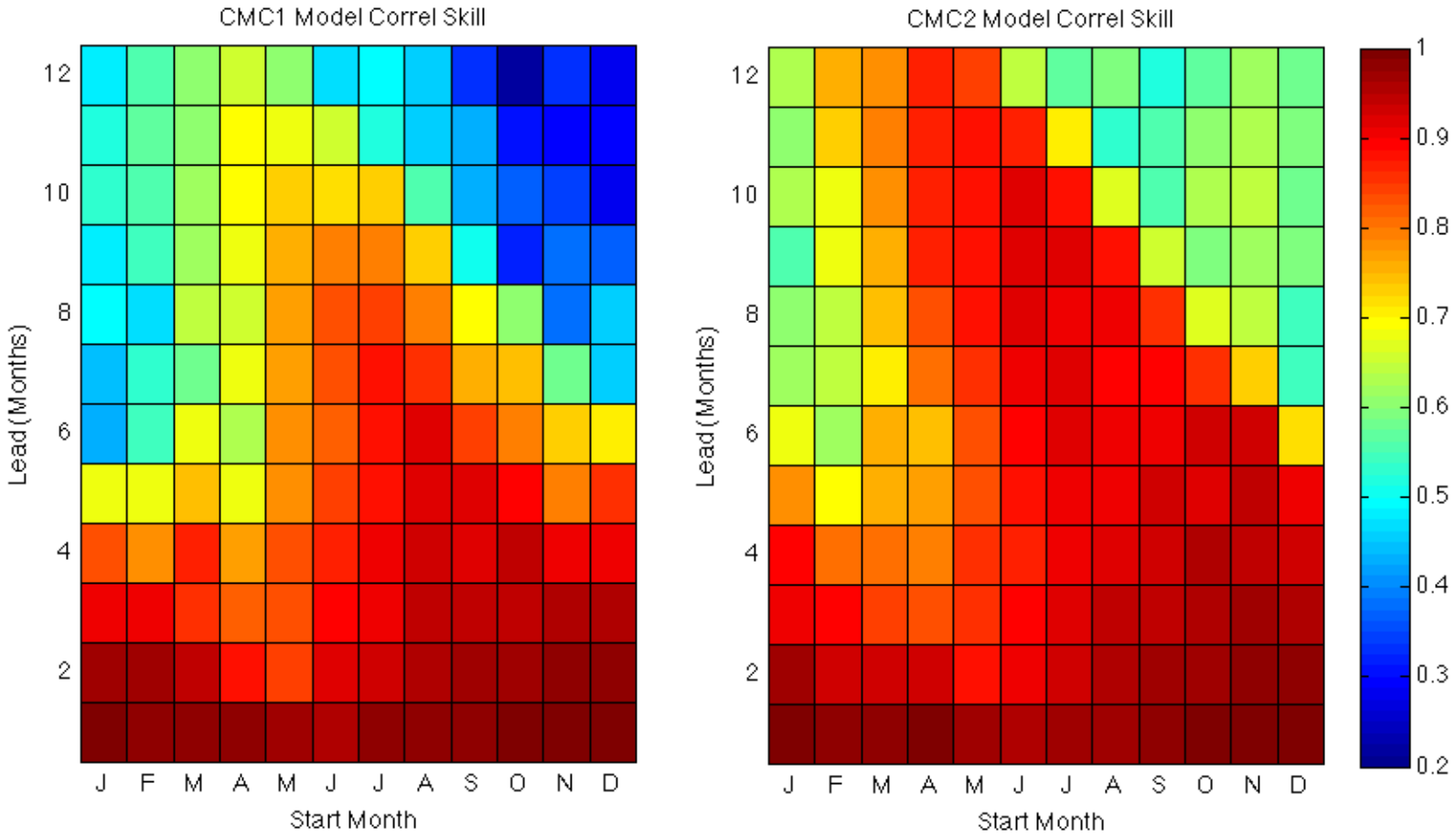
Hindcast Performance Diagnostics:

Individual Models and NMME

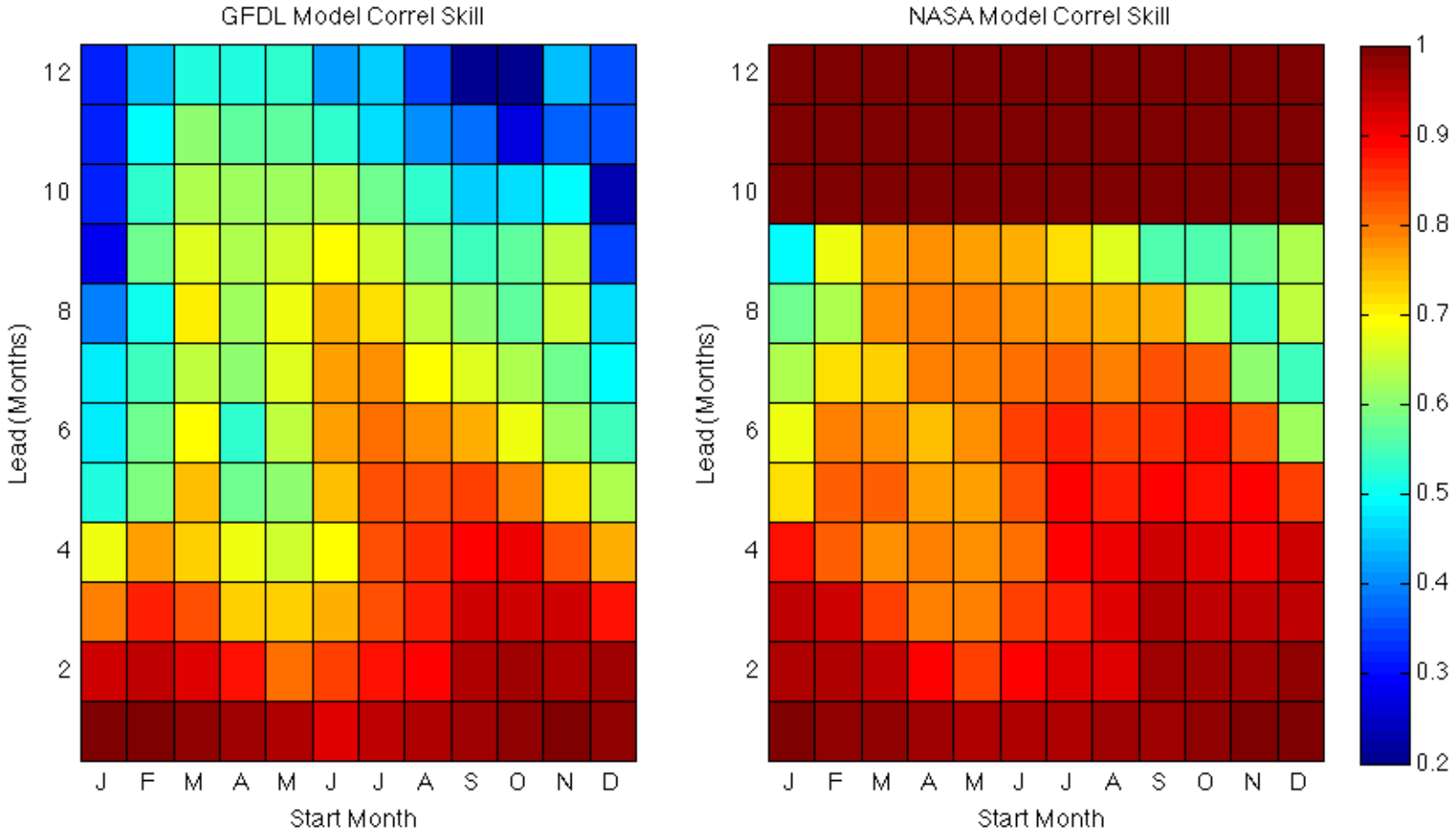
Individual Model Correlation Skill by Start Month and Lead



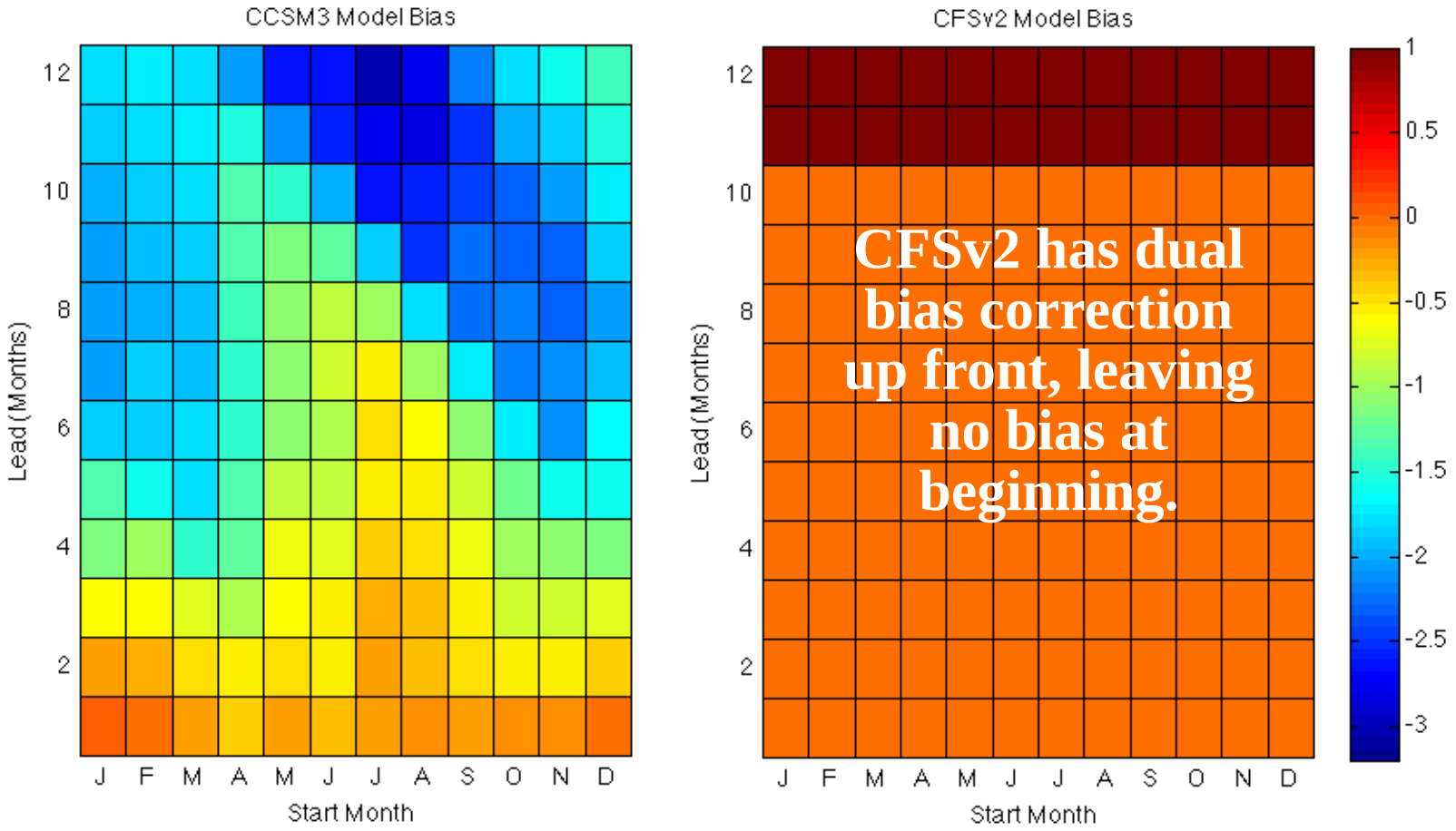
Individual Model Correlation Skill by Start Month and Lead



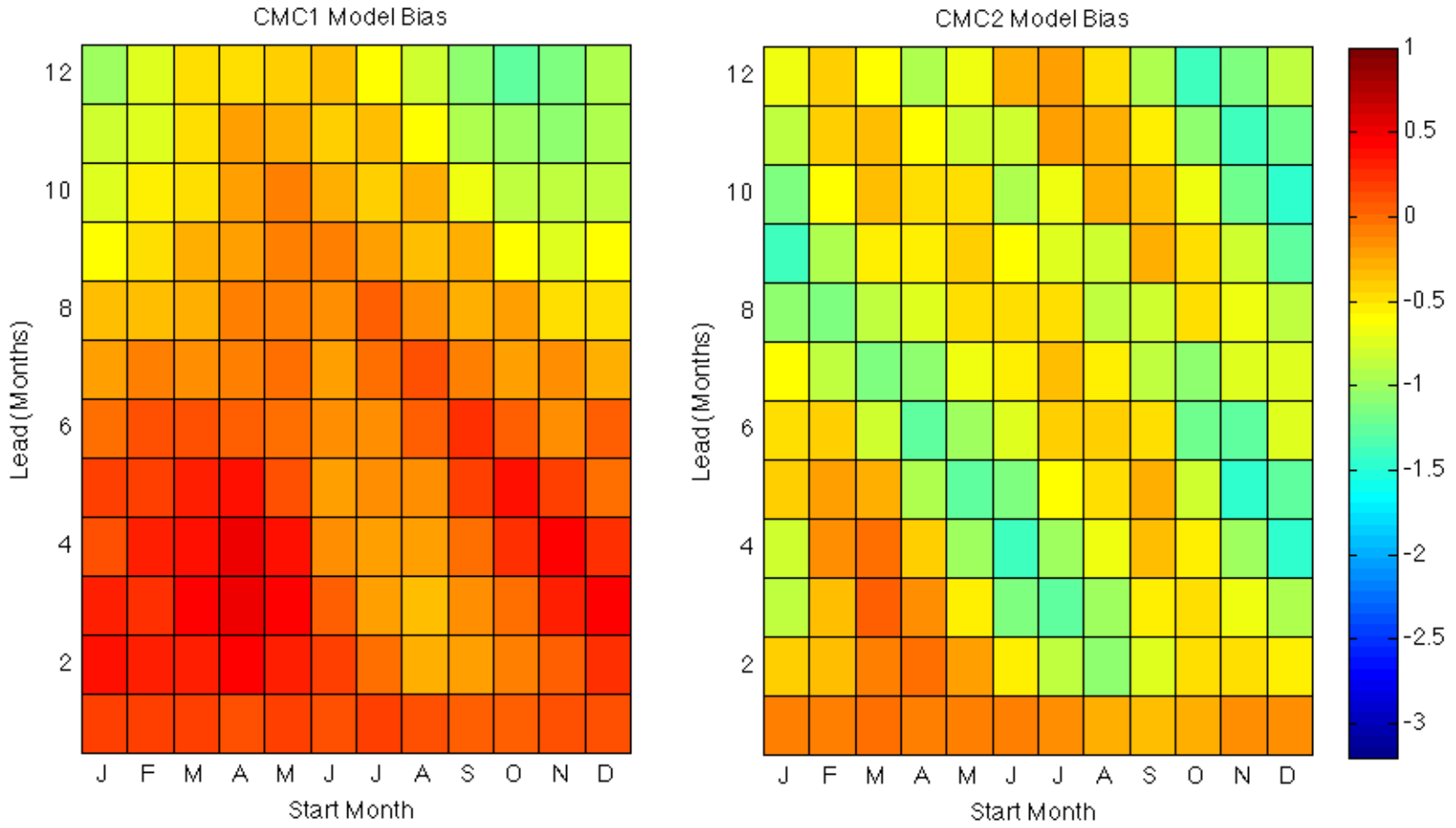
Individual Model Correlation Skill by Start Month and Lead



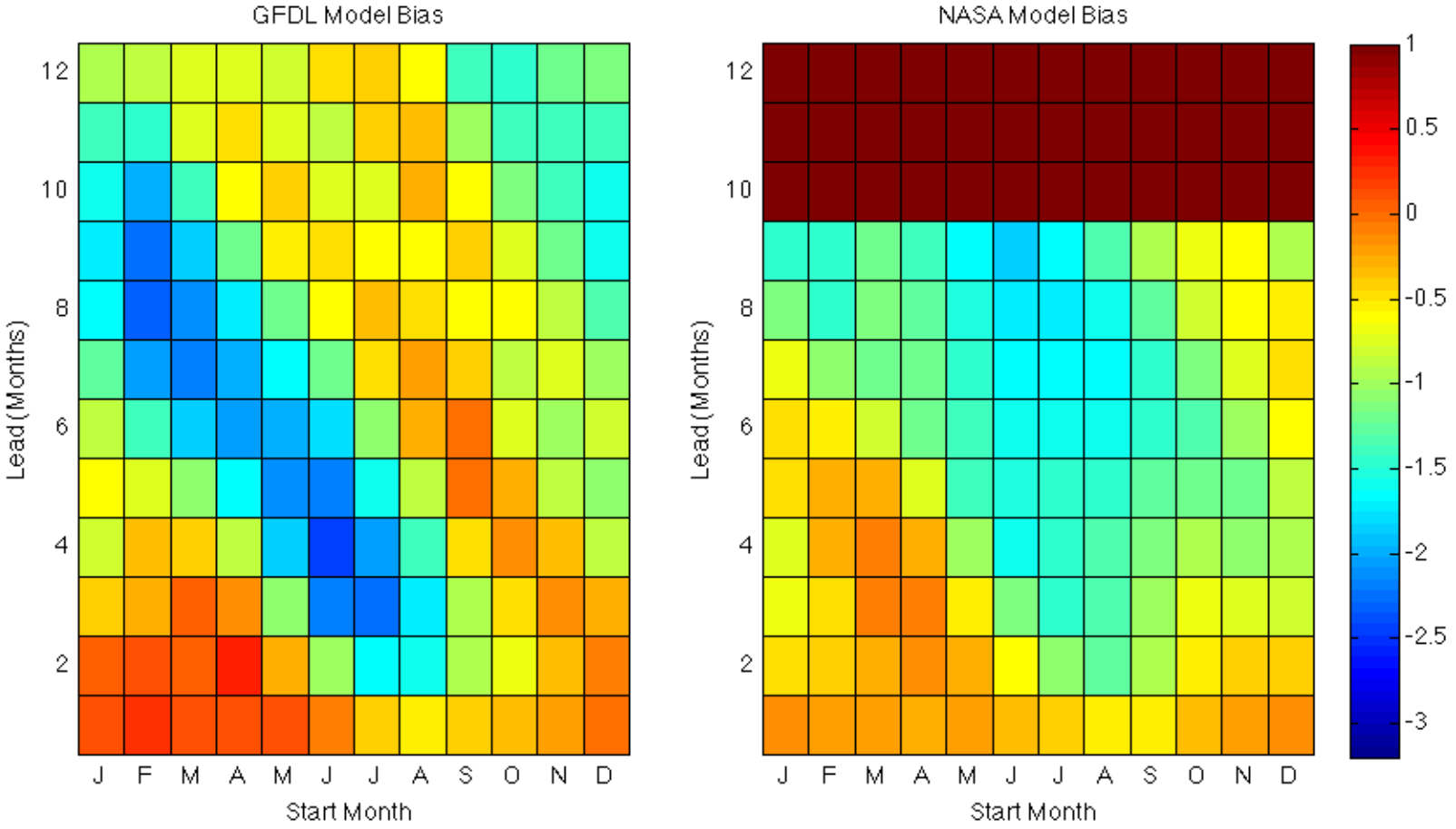
Individual Model Bias by Start Month and Lead



Individual Model Bias by Start Month and Lead

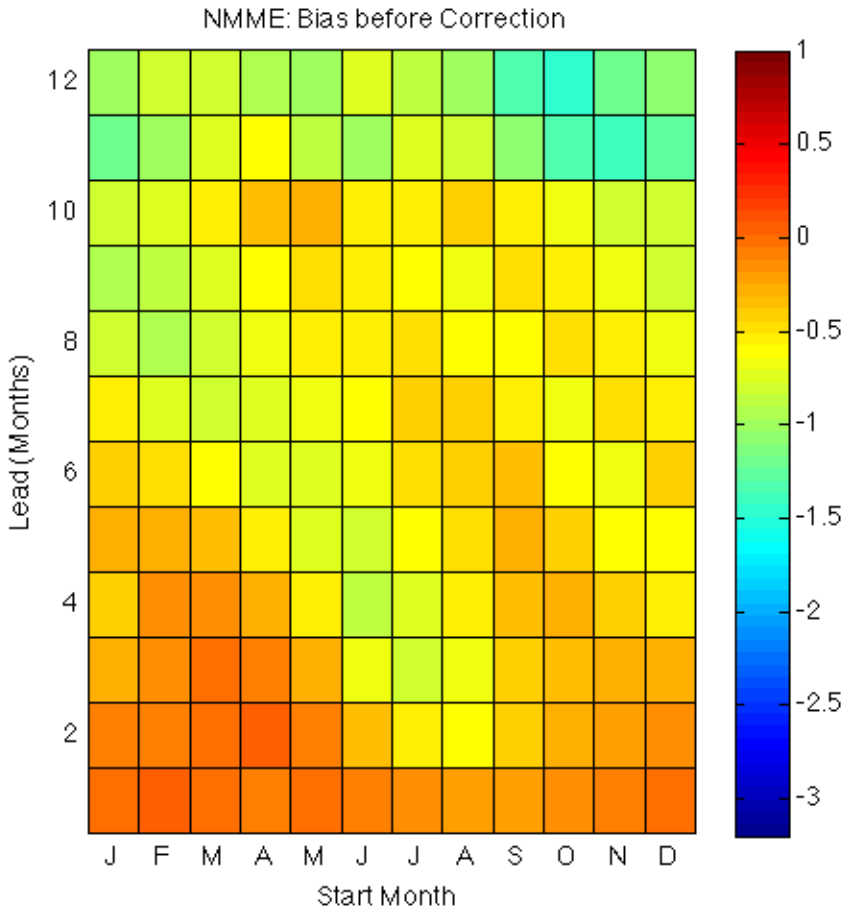


Individual Model Bias by Start Month and Lead



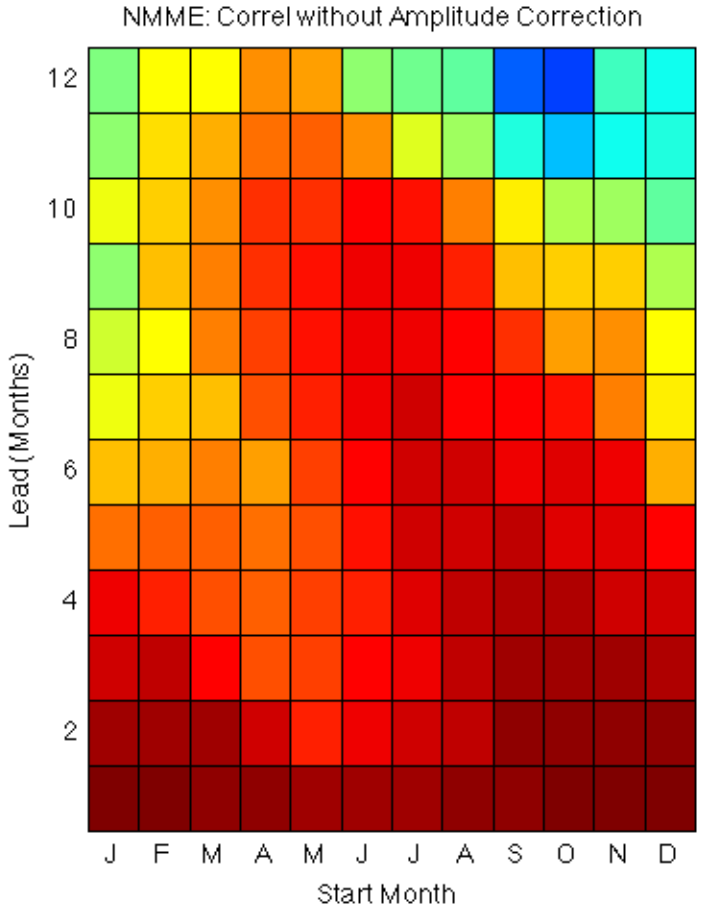
NMME is made with each ensemble member being weighted equally. So, models with more members are effectively weighted more heavily.

NMME Bias

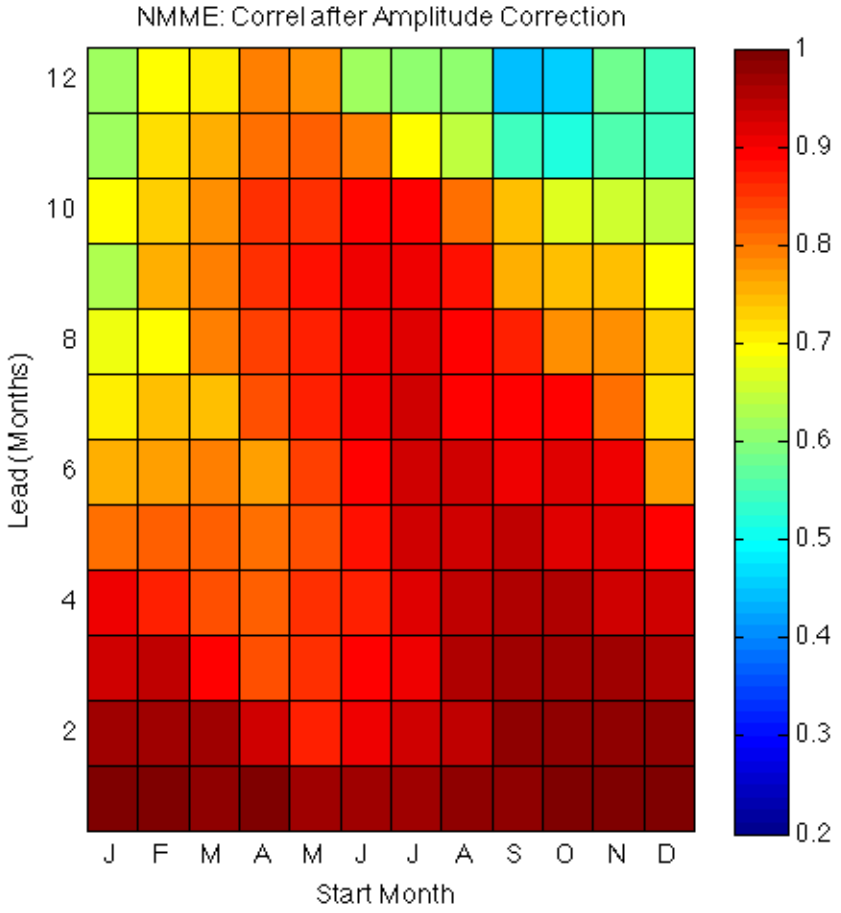

NMME: Bias before Correction
Lead (Months)
12
10
8
6
4
2
J F M A M J J A S O N D
Start Month
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3

NMME Correlation Skill

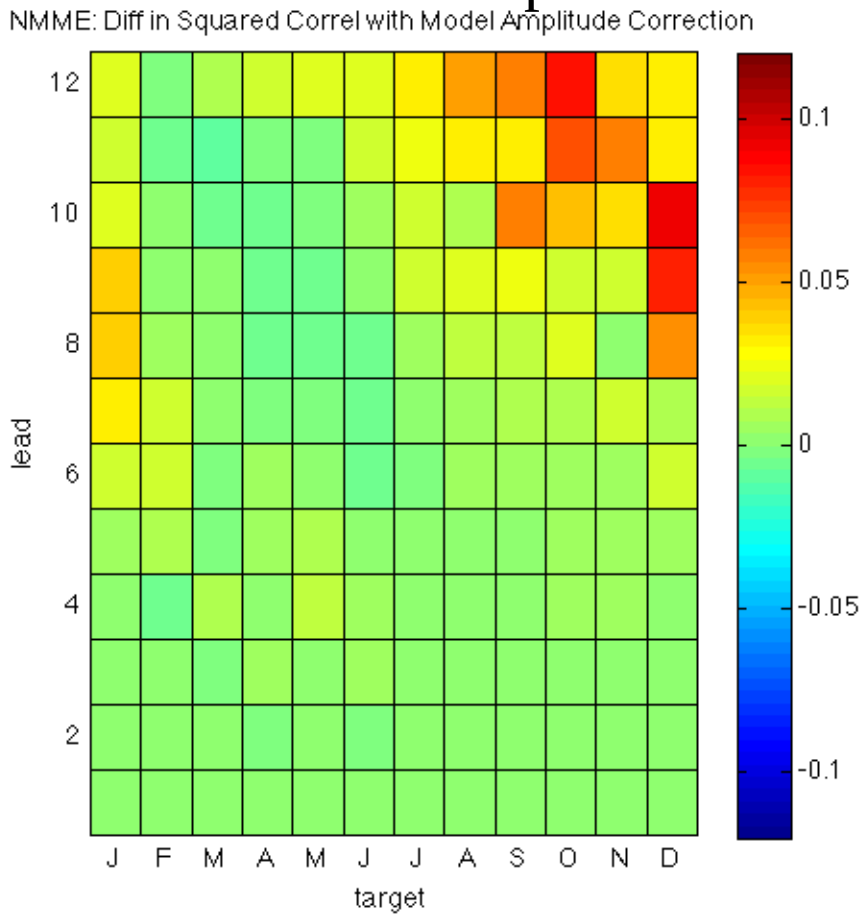
Without Amplitude Correction



With Amplitude Correction

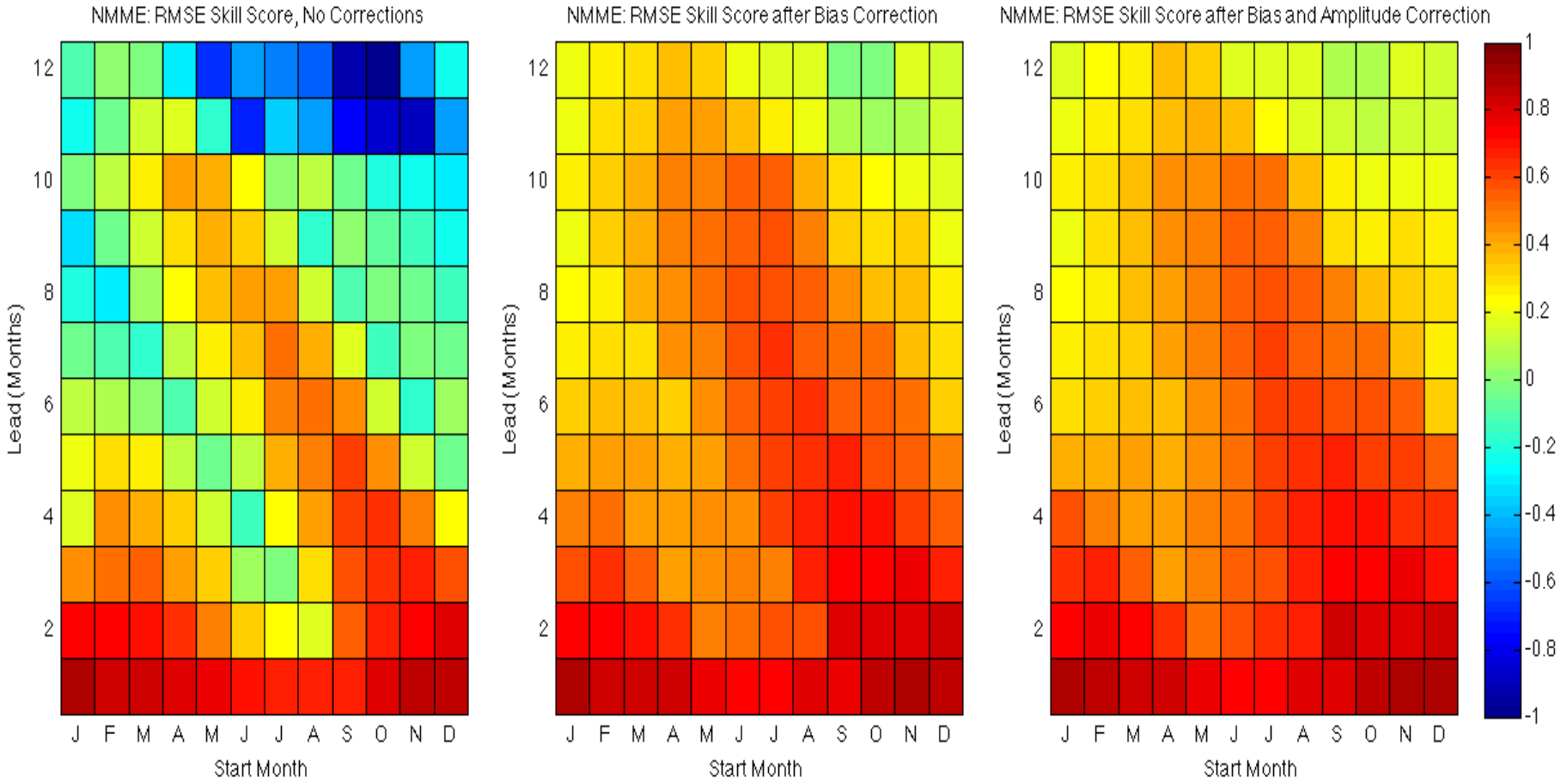


Difference in NMME (Correlation)^2 Skill: **With** Minus **Without** Amplitude Correction



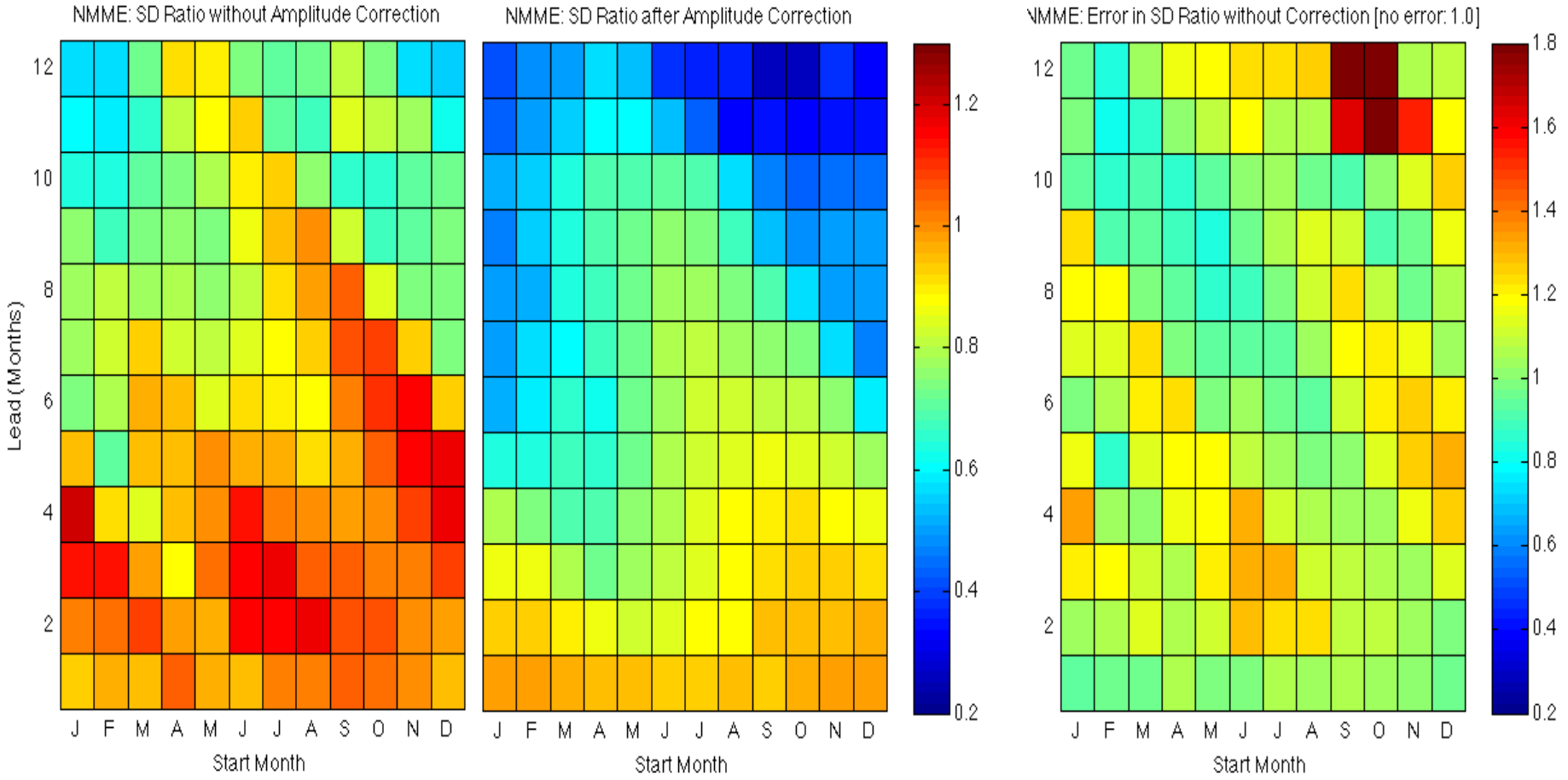
$1 - \frac{RMSE_{fct}}{RMSE_{cli}}$ NMME RMSE Skill Score

No Corrections | Bias Correction | Bias & Amplit Correction



NMME Stand. Dev. Ratio w.r.t. Observations

No Corrections Amplit Correction Ratio: Before/After



Estimation of Forecast Uncertainty

- Using Ensemble Member Spread
- Using Hindcast Skill based Standard Error

The hindcast skill-based standard error of estimate (SEE) provides a reliability-preserving spread:

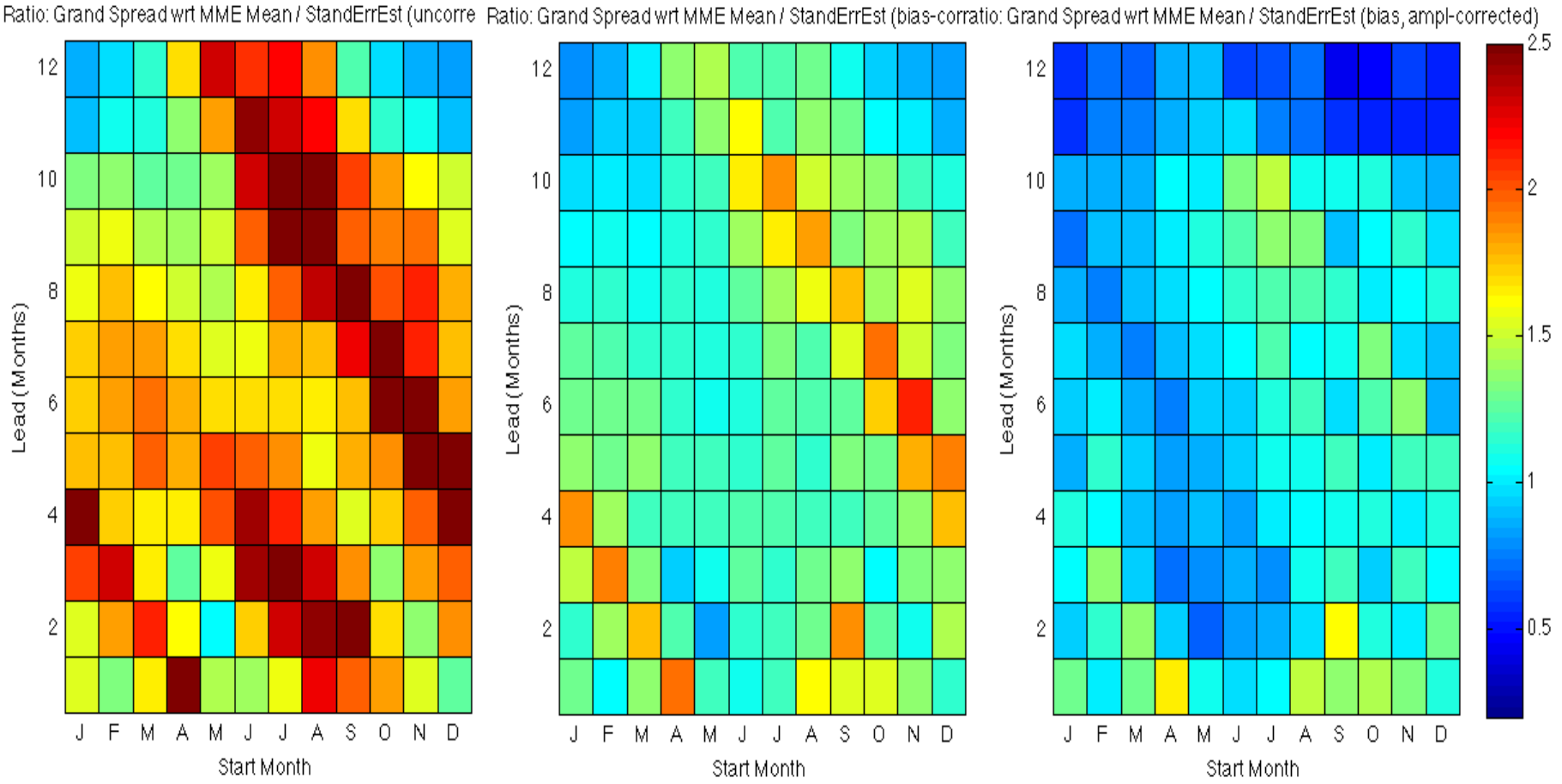
$$SEE = SD_y \sqrt{1 - cor_{xy}^2}$$

where X = system forecasts Y = verifying observations

It would be comforting to see the NMME spread approximate this statistical, skill-based SEE. Let us see if that is the case.

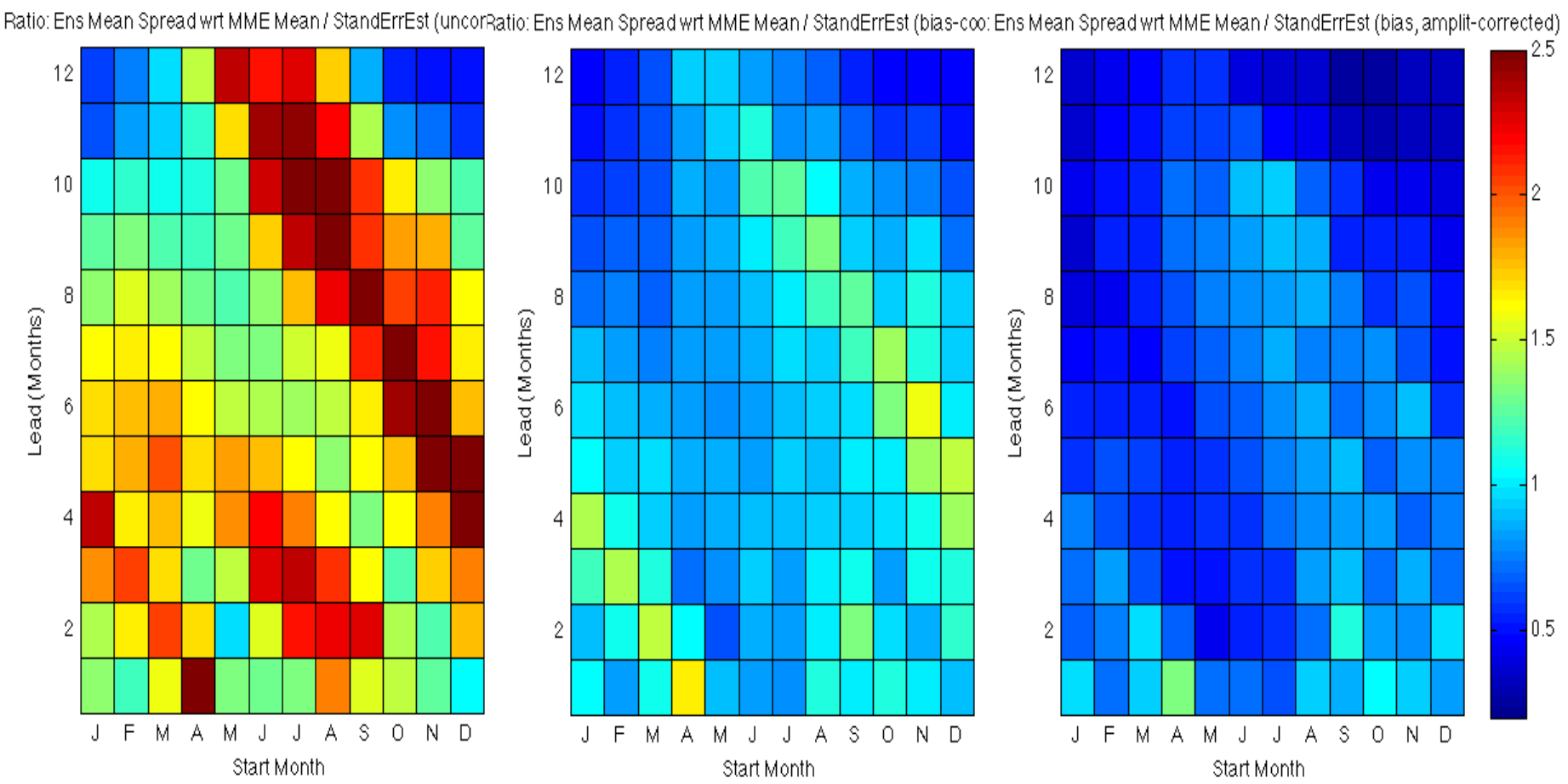
Ratio: Grand NMME Spread / Skill-Based Stand. Error

No Correction | Bias Correction | Bias & Amplit Correction



Ratio: Spread of Ens Means w.r.t. Grand Ens Mean/ Skill-Based Stand. Error

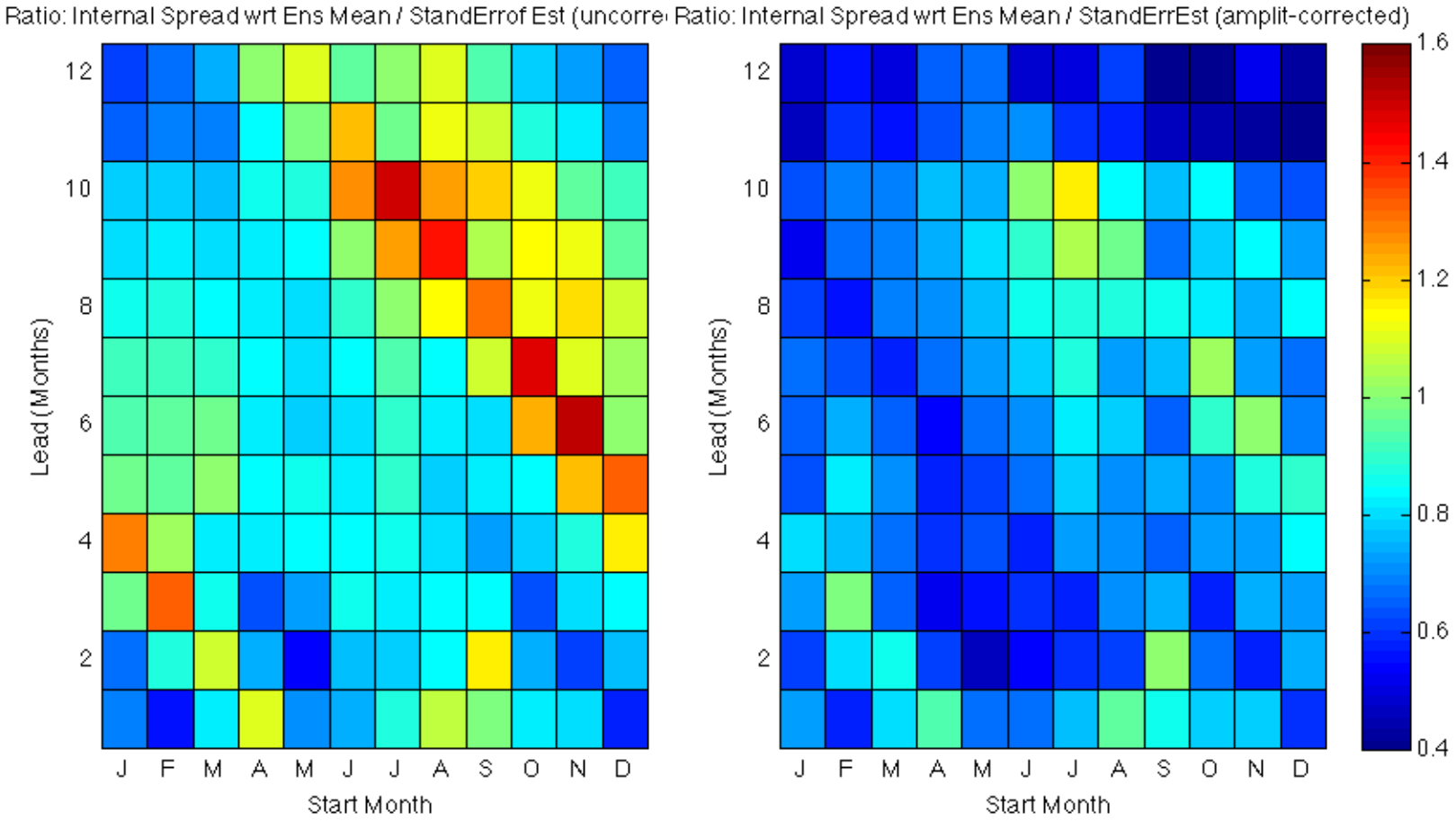
No Correction | Bias Correction | Bias & Amplit Correction



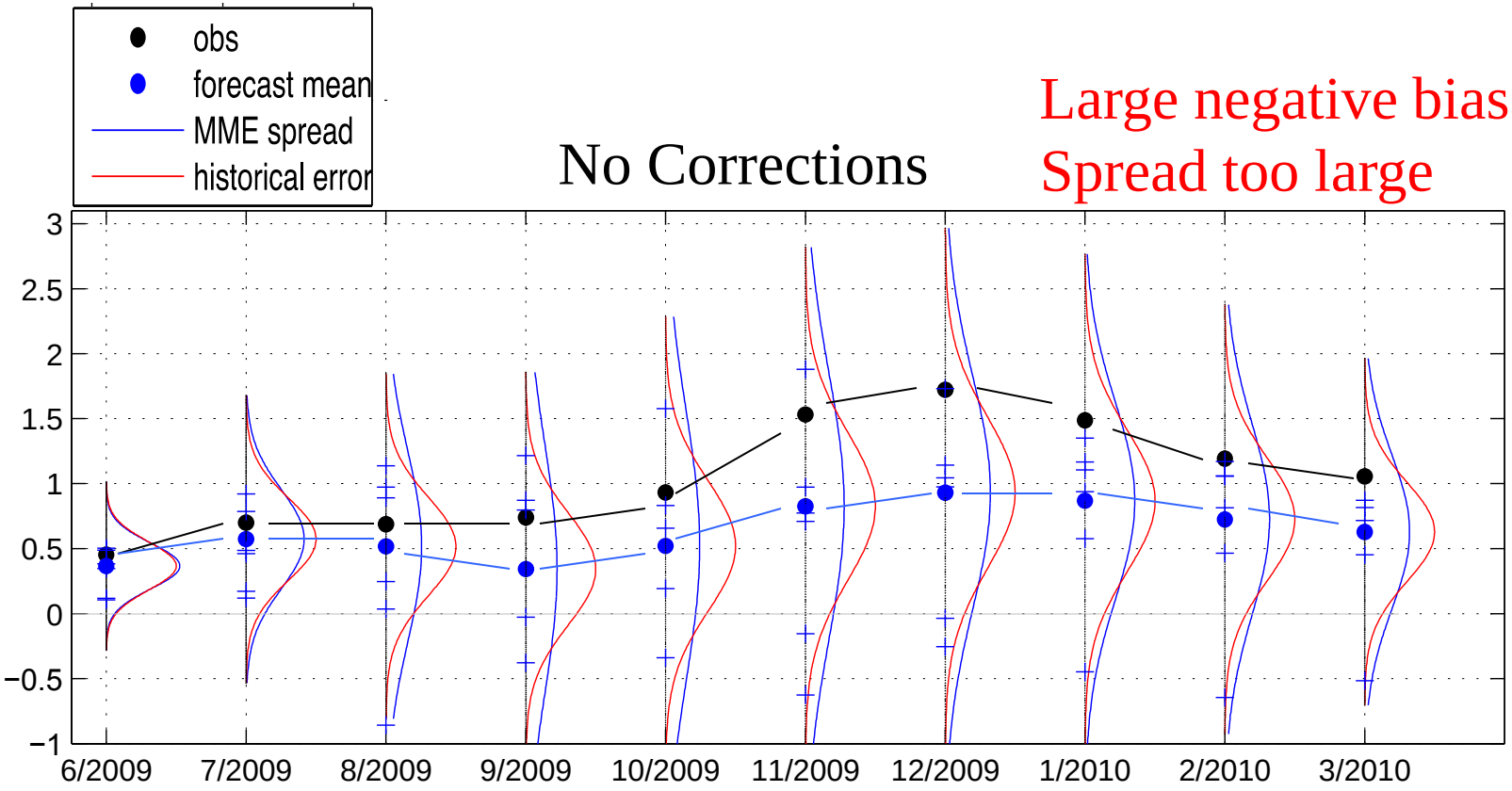
Ratio: Spread w.r.t. Indiv Ens Mean/ Skill-Based Stand. Error

Without Amplitude Correction

With Amplitude Correction



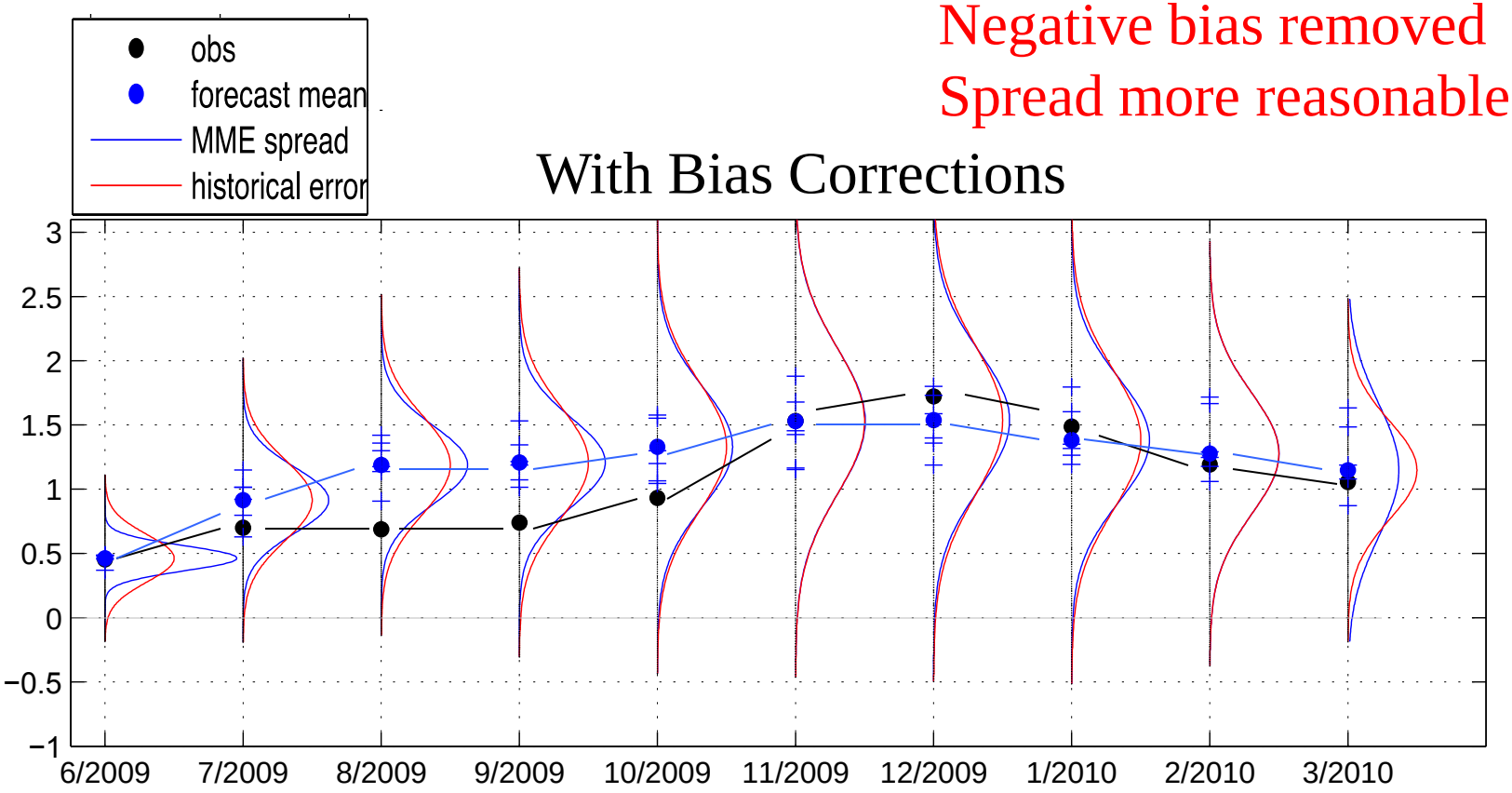
Need to estimate the uncertainty distribution and show it in the plume product.



Months during El Nino of 2009/10

Negative bias removed
Spread more reasonable

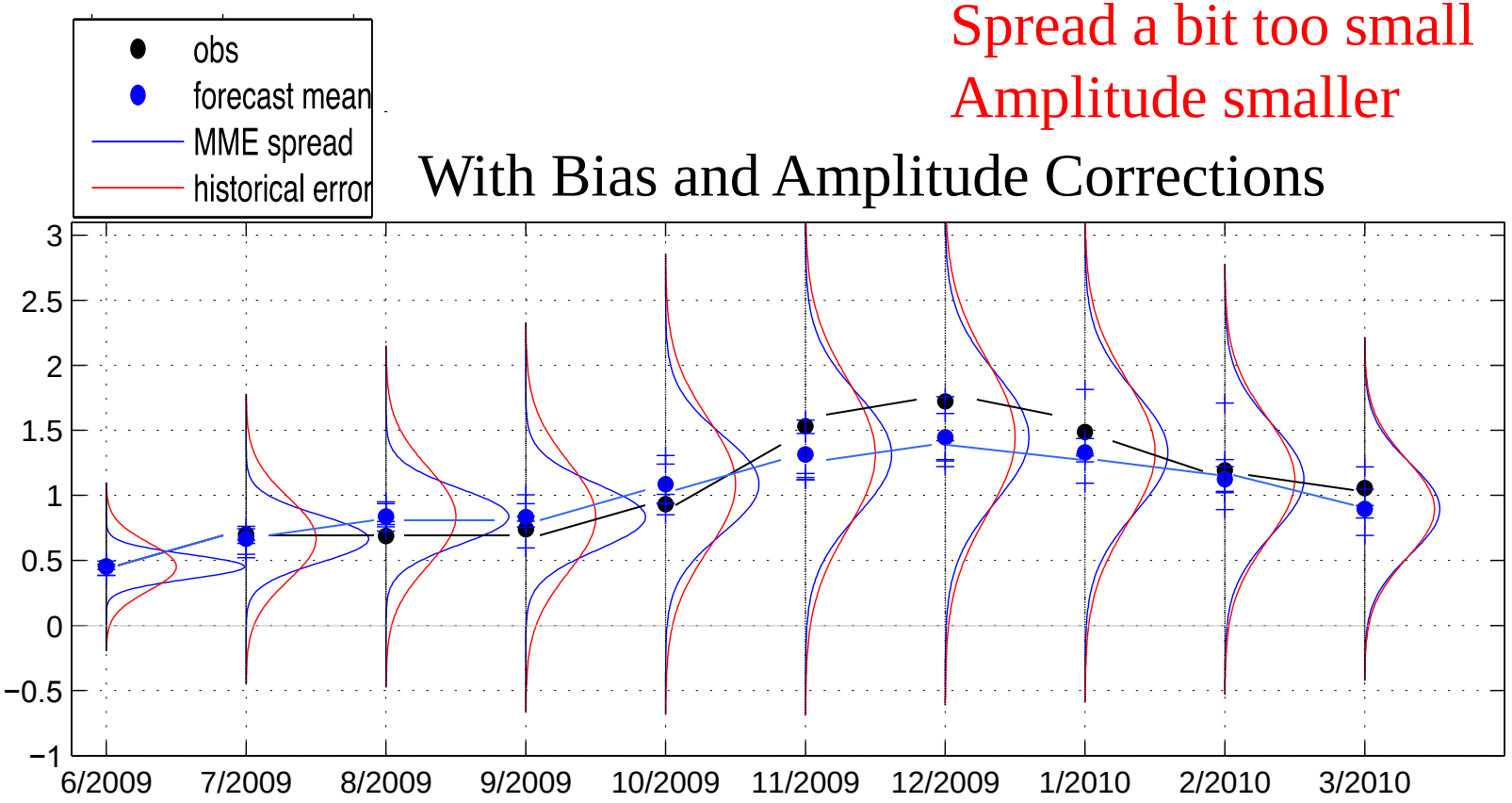
With Bias Corrections



Months during El Nino of 2009/10

Spread a bit too small
Amplitude smaller

With Bias and Amplitude Corrections



Months during El Nino of 2009/10

Some Findings

Multi-model ensemble spread is considerably larger than SEE when the models' differing biases are uncorrected: Ratio is 1.5 to 1.8, and is reduced about halfway to 1.0 after individual model bias corrections.

Even the ratio of spread of individual model ensemble means w.r.t. grand mean to the standard error of estimate is 1.3 to 1.8; model bias corrections reduces it about ¾ of way to 1.0.

Ratio of internal spread around individual model ensemble means to the standard error of estimate is in 0.8 – 1.0 range.

Some Findings (continued)

Correcting forecasts so that the ratio of their interannual SD equals that of observations multiplied by their correlation skill (i.e., amplitude correction) makes less difference in the RMSE of the NMME forecasts than model bias correction, but brings the spread of the MME forecasts within the neighbor-hood of that indicated by the skill-based SEE.

Recommendations and Issues

Correction of model mean biases should be done.

Correction of model amplitude biases should also be done, and it will reduce the interannual variability of the NMME forecasts to be lower than that of the observations, to minimize squared errors. (Some may not like that.)

What is the best way to display the forecast plume for users?